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METHOD OF MEASURING STRESS/STRAIN BY MEANS OF BARKHAUSEN NOISE

The present invention relates to a method of measuring stress/strain by means of Barkhausen noise. The invention is used, for example, for measuring the stress/strain of bolts or rivets at the wing or fuselage of an airplane, particularly during maintenance work.

For example, for tightening bolts, torque wrenches have been used, while simultaneously determining the internal stress in the bolt by means of ultrasonic speed measurements. However, this requires that the bolt is coated or laminated with a piezoelectric which makes the bolt considerably more expensive.

In addition, it is known to use micromagnetic methods and sensors, which are based on the Barkhausen noise, for the detection of material changes as a result of treatment processes. In this case, the recognition is utilized that the magnetic structure of the materials is influenced by the characteristics of the material. Crystallite limits and other inhomogeneities, such as dislocations, foreign atoms and inclusions hinder the movement of the so-called Block walls. The detachment of the walls from inhomogeneities results in

bounces in the magnetization, the so-called Barkhausen noise. By means of a coil, these jolt-type movements of the Block walls can be recorded in the form of brief electric pulses. The number, height and intensity of the pulses depends on the material and the condition.

Such method for the nondestructive characterization of ferromagnetic materials is known, for example, from German Patent Document DE 196 31 311 C2. The measuring principle is based on the fact that, when a ferromagnet is periodically reversed, the magnetic domain structure is continuously changed. When the magnetization is changed, boundaries between areas of the same magnetization (that is, Bloch walls) move through the material structure and interact with the microstructure of the material. This interaction is received as an electromagnetic signal - the so-called Barkhausen noise -.

Such methods, which are based on an analysis of the Barkhausen noise, are generally used for quality control. They are used, for example, for optimizing different treatment processes (grinding, heat treatment, etc.) of components. The components may, for example, be ground parts, camshafts, crankshafts, bearings, gear wheels, injection valves and numerous other parts from automotive engineering and the aerospace field.

It is an object of the invention to provide a method of measuring stress/strain which rapidly and at low equipment expenditures is capable of determining particularly stress/strain conditions of fastening devices.

According the invention, this object is achieved in that an exciting/sensing device is arranged at least adjacent to one magnetic or magnetizable element - preferably at least in a partial area around the magnetic or magnetizable element -; in that the exciting device is acted upon by a rising magnetizing current; in that the starting of the Barkhausen noise in the element is detected as a function of the magnetizing current by means of the sensing device, the starting of the Barkhausen noise being a measurement of the stress/strain condition of the element. Expediently, the starting of the Barkhausen noise is determined by a comparative measurement with respect to reference values.

The invention has the advantage that the physical effect of the Barkhausen noise is effectively utilized. The stress/strain condition of a magnetic or magnetizable (preferably ferromagnetic) element is determined in a contactless manner by a simple mounting of an exciting/sensing device. In this case, the element is magnetized by the magnetic field generated by the exciting device, and the

sensing device detects the Barkhausen noise.

It is particularly expedient to construct the exciting/sensing device in one piece, preferably by means of a single coil which acts simultaneously as an exciting device and a sensing device. In this case, the sensing device detects the magnetizing current at which the Barkhausen noise occurs, the magnetizing current being proportional to the internal stress in the element. Such an arrangement has the advantage that the equipment expenditures are kept as low as possible.

According to an alternative embodiment, the exciting device is again constructed as a coil. However, the sensing device for detecting the Barkhausen noise is an acoustic or interferometric detector. Such sensors are advantageously distinguished particularly by small dimensions.

A pulsed magnetizing current is expediently used, in which case, during the off-time of the pulses, the sensing device is set to receive the Barkhausen noise. This has the advantage that higher magnetic fields can be generated without thermally overloading the exciting device.

According to a preferred embodiment, it is advantageous to arrange an intermediate element of a non-magnetic or non-

magnetizable material between the magnetic or magnetizable element and a structure (for example, a component) to be connected therewith. The magnetic or magnetizable element is, for example, a fastening device in the form of a bolt, and the intermediate element may be a washer or the like. This embodiment has the advantage that the stress existing in the fastening device as a result of the fastening is measured directly. The washer is optional and preferably consists of a non-ferromagnetic material.

According to an alternative embodiment, it is expedient to first arrange a magnetic or magnetizable element between a non-magnetic or non-magnetizable fastening device and a structure to be connected therewith. Advantageously, stress/strain conditions of a non-magnetic fastening device can therefore also be determined because the mechanical stress is measured which is transmitted by the fastening device to a preferably ferro-magnetic element (for example, a washer).

The method according to the invention is preferably used when measuring stress/strain conditions of fastening devices (such as screwed or inserted bolts, rivets, etc.). The method can be used in multiple manners, for example, in the maintenance of airplanes, helicopters, motor vehicles, etc.

In the following, the invention will be described in

detail by means of the attached drawings.

Figure 1 is a schematic representation of a preferred embodiment for implementing the method according to the invention;

Figure 2 is a view of representations of experimental measured values of the Barkhausen noise;

Figure 3 is a schematic representation of a measuring arrangement as an alternative to Figure 1; and

Figure 4 is a schematic representation of an alternative measuring arrangement by means of a riveted connection.

Figure 1 shows a bolt 4 which is connected with a structure 6. As a rule, the bolt 4 is used for the fastening, fixing or holding of the structure which may comprise several components. The connection between the bolt 4 and the structure 6 may be screwed, riveted, inserted or the like. In the case of the screwed bolt illustrated in Figure 1, a washer 5 is as a rule arranged between the head 4a of the bolt and the structure 6.

For determining the stress/strain condition of the bolt 4, in a first step, the coil, which has the reference number 1

in Figure 1, is fitted over the head 4a of the bolt. However, the coil 1 can also be fitted onto the head 4a or be arranged adjacent to the bolt 4. According to a preferred embodiment, the coil is used for generating a magnetic field as well as for detecting the Barkhausen noise, which in the following will be described in greater detail. However, instead of the individual coil 1, separate components can also be used; for example, a first coil, which is used for generating the magnetic field, as well as a second coil which is used for detecting the Barkhausen noise. In the following, reference will be made to the alternative embodiment, in which the exciting coil has the reference number 2 and the sensor coil has the reference number 3, in each case by placing the corresponding components in parentheses.

The coil 1 (or the exciting coil 2) is first used as a magnetizing coil and is excited by means of a magnetizing current for generating a magnetic field. If the bolt 4 consists of a ferromagnetic material, the magnetization field has the effect that the molecular magnets are aligned by the magnetic field of the coil 1 (or the exciting coil 2) through which the current flows. As known, the flipping-over of the molecular magnets is an erratic process (see Figure 2) which results in a change of the magnetic flux, whereby a tension change is induced in the coil 1 (or in the sensing coil 3). In this case, the start of the flipping-over or alignment of

the molecular magnets is a function of the magnetizing field intensity or of the magnetizing current as well as of internal mechanical stress in the material. In this case, a tensile stress applied to the bolt 4 acts against the alignment of the molecular magnets, or the molecular magnets start to flip over again into their original alignment. This flipping-over of the individual molecular magnets, in turn, generates a change of the magnetic flux, whereby currents (the so-called Barkhausen noise) are induced in the coil 1 (or in the sensing coil 3). Since the magnetic field intensity required for the magnetizing of the bolt 4, or the magnetizing current is also a function of the internal mechanical stress, the stress/strain condition of the bolt 4 can be determined. In other words, a continuously rising magnetizing current generates a continuously rising magnetic field in the coil 1 (or the exciting coil 2), in which case the magnetizing current present at the start of the Barkhausen noise is a measurement of the tensile stress applied to the bolt 4.

As a rule, a pulsed magnetizing current is used for keeping the thermal loading of the coil 1 (or of the exciting coil 2) as low as possible. Simultaneously, the start of the Barkhausen noise is monitored as a function of the magnetizing current through the coil 1 (or through the sensor coil 3). The measurement takes place inductively, the coil 1 in each case being set during the off-time of the pulses of the

magnetizing current to receive the Barkhausen noise. For the precise determination of the stress/strain condition, comparative measurements are used as the reference which had been determined beforehand at the bolts (or rivets, etc.) made of the same material and of the same geometry. The stress/strain condition is therefore determined by comparative measurements with previously determined measured values, for example, electronically filed in a table.

In addition, it should be noted that, during the measurement of the stress/strain condition of a, for example, ferromagnetic bolt, a washer made of a non-magnetic or non-magnetizable material should be used which, in the following, analogous to Figure 1, has the reference number 5'.

In addition, by means of the method according to the invention, the stress/strain condition of a non-magnetic or non-magnetizable bolt can also be determined which, analogous to the previous indicating method, in the following, will have the reference number 4'. In this case, a washer 5 made of a magnetic or magnetizable material is used, so that the stress transmitted from the bolt 4' to the washer 5 is correspondingly determined by means of the above-described measuring method.

As an alternative, instead of being determined

inductively by means of a sensing coil 3, the Barkhausen noise can be detected by means of an acoustic or interferometric detector 7, which is schematically illustrated in Figure 3. The principle on which the invention is based is unchanged, only the Barkhausen noise is determined in a different fashion. The detector 7 may, for example, be a microphone or a piezoelement, to mention only a few examples.

Figure 4 shows another alternative measuring arrangement on the example of a riveted connection. In Figure 4, the rivet has the reference number 8 and the structure equipped therewith, corresponding to the indicating method in Figure 1 or Figure 3, has the reference number 6. In addition, in Figure 4, the exciting coil 2 and the sensing coil 3 are illustrated separately as wire-wound coils around a core 9. The exciting coil 2 is again acted upon by a variable magnetization, and the sensing coil 3 detects induced stress by flipping over the domains. Instead of the sensing coil 3, an acoustic or interferometric detector 7 can also be used here for the detection of the Barkhausen noise.